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RICE EXPERIMENT STATIONS IN INDIA[1]

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INDIA has 73 million acres of land under rice cultivation with an annual production of 22 million tons. The rice acreage constitutes about 30 per cent of the cultivated land in the country and the largest area in any country in the world under this crop.

Rice is cultivated in India under widely varying conditions of soil, climate and rainfall. The crop is grown in almost all parts of the country, but it is mostly concentrated in the river valleys, deltas and lowlying coastal areas in southern and north-eastern India, including the states of Assam, Andhra, Bihar, Bombay, Hyderabad, Madhya Pradesh, Madras, Orissa, Travancore-Cochin, Utta Pradesh and West Bengal. From these states 95 per cent of the rice crop of the country is produced.

Systematic rice breeding started in India 45 years ago. Beginning in Bengal in 1911 with Madras immediately following, rice breeding and research work has quickly spread to all other rice growing states and today there are now 69 rice research stations, distributed all over India. All these research stations, except the Central Rice Research Institute, which is under the Union Government, are operated by the state governments as shown in Table 1 below.

1 *For lack of space this paper has been considerably condensed from the original one submitted for publishing in the News Letter — Editor's note.*

Table 1. Rice Research Stations in India.

State	No. of stations	State	No. of stations
Assam	3	Madhya Pradesh	1
Andhra	5	Mysore	1
Bihar	4	Orissa	3
Bombay	15	Punjab	2
Coorg	1	Travancore-Cochin	6
Hyderabad	4	Uttar Pradesh	4
Kashmir	2	West Bengal	5
Madras	11	Union Government	1
Madhya Bharat	1	Total	69

Rice research in the country has received considerable impetus from the Indian Council of Agricultural Research, established in 1929, which has been aiding a number of rice research projects in these stations.

All the rice research stations in the states are largely concerned with the production of better varieties. Due to the enormous variations in rice growing conditions in the country, the varietal diversity is apt to be very great and so thousands of varieties are now grown in different parts of the country. With a few exceptions, almost all the improved strains of rice have been evolved by selections from local varieties. So far a total of 430 improved strains has been evolved as shown in Table 2 below.

Table 2. Number of Improved Rice Strains in India[1]

State	No. of strains	State	No. of strains
Assam	30	Mysore	24
Andhra	46	Orissa	31
Bihar	13	Punjab	7
Bombay	45	Travancore-Cochin	14
Hyderabad	13	Uttar Pradesh	24
Madras	110	West Bengal	55
Madhya Pradesh	18	Total	430

Twenty-seven of these strains have been evolved by hybridization.

The breeding objectives of the rice research stations are high yield, earliness, stiff straw, grain quality, resistance to disease and, in some localities, adaptability to deep water conditions, resistance to salinity and floods, etc. In most cases, investigations on manurial and cultural practices are also included in the research program, as they greatly affect crop yield.

Since the state experiment stations are primarily concerned with rice breeding and some agronomical investigations, such fundamental studies as genetics and physiology are only incidental to them, except for a few stations where such fundamental investigations are intensively carried on.

A brief review of some of the rice experiment stations in the country is given below:

The Central Rice Research Institute, Cuttack

The Central Rice Research Institute, located at Cuttack, 256 miles south of Calcutta, was established by the Government of India in 1946 to undertake fundamental research in all aspects of rice, to investigate such problems as have wide application in the country, and to serve as a centre for scientific information on the crop.

The Institute, occupying an area of 250 acres, is organised into eight research divisions of Botany, Agronomy, Plant Pathology, Agricultural Entomology, Agricultural Chemistry, Statistics, Plant Physiology and Agricultural Engineering (the last two divisions just being organized). In addition, there are the Farm and Administrative Divisions. The Institute also provides facilities for training and conducts extension work in a nearby Intensive Cultivation Centre, covering about 8,000 acres.

The Institute has a very extensive collection of world rice genetic stocks and is now one of the five centres under the FAO project for the maintenance of the genetic stocks registered in the World Catalogue of Rice, issued by FAO.

This collection is being examined and used for breeding purposes. Among the collections from China, some varieties have been found early maturing and high yielding, while others resistant to blast and helminthosporium diseases. Some Taiwan varieties are very promising under Kashmir conditions.

Under the sponsorship of FAO and the Indian Council of Agricultural Research, an extensive hybridization program between the *japonica* and *indica* rices has been undertaken for several years at the Institute, with the object of providing several South and South-East Asian countries and Indian states with breeding materials for evolving new strains which can combine the *japonica* characteristics of high yield and responsiveness to heavy fertilization with the hardiness and adaptation to tropical conditions of the *indica* rice.

Under this cooperative hybridization project, 192 *indica* varieties, selected by the

participating countries and Indian states, were crossed at the Institute to several *japonica* varieties contributed by Japan. In all, 710 *japonica–indica* cross combinations were made and hybrid seeds distributed to all participating countries for growing under local conditions. The selections from this hybrid material that have been grown in India and the participating countries were reported to be very promising.

Work is currently in progress at the Institute for breeding new varieties that are resistant to disease, early maturing, high yielding and non-lodging. Under a scheme sponsored by the Indian Council of Agricultural Research, a survey of the Jeypore tract of Orissa, considered as a secondary centre of the origin of rice, is now in progress and several hundred samples of rice have already been collected.

Fundamental studies at the Institute include studies on the inheritance and linkage relationship of several characters, sterility in interspecific and inter–racial hybrids, species relationship and origin of rice and embryoculture of interspecific hybrids.

The manurial investigations of the Institute are designed to study the optimum as well as economical doses of different nitrogenous fertilizers for the rice crop, the comparative efficiency of different organic manures and inorganic fertilizers, methods and time of application of different fertilizers, and the cumulative and residual effects of fertilizers on soil fertility.

Under a scheme sponsored by the Indian Council of Agricultural Research the value of some 60 different green manuring crops, collected from different rice growing countries in the world, is being studied for green manuring of the rice crop. Among the cultural investigations that are now in progress, mention may be made of crop sequence experiments, designed to determine the suitability of ground–nut, wheat, cotton, gram and oil–seeds for growing in sequence with rice; double cropping experiments and trials of herbicides for control of rice weeds.

The plant pathological investigations of the Institute are concerned with the study of blast and helminthosporium diseases, including their origin and spread, susceptibility of various rice varieties to their attack, estimation of losses and methods of control.

The entomological investigations of the Institute cover both field and storage pests of rice. Among the field pests work is being concentrated on gall flies and stem borers, together with methods of their control. Similarly investigations are in progress on rice storage pests.

In the Agricultural Chemistry Division work is presently in progress on investigating the chemical and physical properties of water–logged rice soils and on studying the nutrient elements and their availabilities for crop production. Investigations are also in progress on the mineralisation of soil organic nitrogen and the uptake of phosphate by plants under water–logged conditions.

As regards statistics and field experimentation, sampling studies for estimation of crop yields and losses due to insect pests and diseases and studies on the various

methods of layout for field experiments are in progress at the Institute.

The Institute provides short term training courses at various levels from time to time in cooperation with Orissa State. The Institute has held two international training courses on rice breeding under the sponsorship of FAO.

Rice Research Stations in the States

Assam: This state, situated in the north–east of India, produces about 1.6 million tons of rice on 3.0 million acres of land planted to it.

In the state there are three rice research stations, located at (1) Karimganj, (2) Titabar and (3) Rohu.

The Karimganj station was established in 1913 but systematic breeding work did not begin until 1921. This station is for work on *Ahu* or summer and autumn rice, *Bao* or deep water winter rice and *sali* or transplanted winter rice for the Surma valley in the state.

The Titabar station was established in 1923 for work on *Ahu* and *Sali* rice in the Brahmaputra valley.

The Rohu station was started in 1948 for work on *Bao* and *Boro* or spring rice and since 1954 breeding for flood resistant varieties has been added. This station was started to replace the station at Habiganj, which was transferred to Pakistan during the time of Partition in 1947.

A total of thirty improved strains has been released by these stations.

West Bengal: West Bengal, situated in eastern India, has 9.6 million acres under rice cultivation and produces about 3.6 million tons of rice a year. Dacca, which is now in East Pakistan, used to be the chief centre of rice research for the whole of Bengal before partition. In West Bengal at present there are five research stations, located at Chinsurah, Bankura, Suri, Gosaba and Kalimpong. The Chinsurah station, which serves the alluvial region of the state, was started in 1932. The Bankura station, which serves the laterite region of the state, was also started in 1932, with a sub–station at Suri.

The Gosaba station was recently started for breeding saline resistant strains, while the Kalimpong station was started in 1949 to serve hill tracts. The work at these two stations is being financed by the Indian Council of Agricultural Research.

A total of 55 improved strains has been issued.

Orissa: This state has 9.5 million acres of land under rice cultivation with an annual production of 2.1 million tons. It has three rice research stations, located at Bhubaneswar, Berhampur and Jeypore. The chief rice research centre of the state was formerly located at Cuttack, but in 1946 it was transformed into the Central Rice Research Institute. Of the three research stations in the state, the Bhubaneswar station was recently started. So far 31 improved strains have been released: 8 from Berhampur, 7 from Jeypore and 16 from the former Cuttack station.

Andhra: Andhra state, situated in South India on the eastern coast, has 4.3 million acres of land under rice cultivation and it has five rice experiment stations, located at (1) Samalkot, (2) Maruteru, (3) Buchireddipalem, (4) Pulla and (5) Masulipatam.

These stations together have produced 46 improved strains. Some of them are resistant to floods and saline conditions, while a few others are blast resistant.

The research station at Samalkot was started in 1902 first for work on sugarcane and later in 1909 began work on rice improvement. The other stations of the state were established at a much later date, with the Maruteru station established in 1925, the Buchireddipalem station in 1937, the Pulla station in 1950, and the Masulipatam in 1954.

Madras: Madras state, situated in South India beyond Andhra, has 6 million acres of land under rice cultivation. The rice area in the state may be divided into four zones as follows:

1. west coast region with a rainfall of 100–150 inches;
2. central and east coast region with a rainfall of about 30 inches in the centre and about 45 inches in the east coast;
3. Cauvery deltaic area with about 40 inches of rainfall; and
4. southern region with 25–35 inches of rainfall.

Investigations on rice in the state were started with the opening of the paddy breeding station in Coimbatore in 1913, and at present there are 11 rice experiment stations in the state, located at Coimbatore (1913), Aduthurai (1922), Pattambi (1927), Pattukkottai (1935), Ambasamudram (1937), Tirukuppam (1945), Mangalore (1942), Paramakudi (1953), Palur (1905), Taliparamba and Ambalvayal (1945), with Coimbatore as the chief centre of rice research in the State.

The stations at Pattambi, Mangalore, Ambalavayal and Taliparamba serve the west coast region; those at Coimbatore, Palur an Tirukuppam serve the central and east coast region; those at Aduthurai and Pattukottai serve the Cauvery deltaic area; and those at Ambasamudram and Paramakudi serve the southern region.

These stations together have released a total of 110 improved strains for general cultivation.

Travancore–Cochin: Travancore-Cochin state, situated on the southern extreme of India on the western coast, has 1.1 million acres under rice cultivation with an annual production of 0.3 million tons. It has six rice experiment stations, located at Nagercoil, Monkompu, Kottarakara Alwaye, Ollukara and Onattukora. Of these stations, the one at Nagercoil is the oldest, established in 1914. So far a total of 14 improved strains has been released.

Mysore: Mysore state in South India, with about 800,000 acres under rice cultivation and an annual production of some 0.2 million tons, has one rice experiment station, located at Nagenhalli. It was started in 1917 as a demonstration farm and

in 1928 it was converted into a rice experiment station. So far 21 improved strains and three hybrids have been released.

Hyderabad: Hyderabad state, situated in South India, has 1.3 million acres under rice cultivation with an annual production of 0.3 million tons. Nearly 95 per cent of the rice acreage is in the eastern part of the state. The rainfall in this area is about 30 inches. Forty-five per cent of the rice area is double-cropped. There are four rice experiment stations, located at Himayetsagar, Rudroor, Dandi, and Dhanesagur.

The Himayetsagar station, the chief rice research centre of the state, started in 1928 and was greatly expanded in 1950, to cover breeding, agronomic investigations, soil studies and control of pests and diseases. The other three stations are comparatively recent establishments. A total of 13 improved strains has been released.

Bombay: Bombay state, situated along the western coast of India, has 2.9 million acres under rice cultivation with an annual production of one million tons. The crop is chiefly cultivated on the narrow coastal strip between the sea and the Western Ghats. The rice area of the state can be divided into seven regions according to the amounts of rainfall.

Rice research in the state has received considerable attention. Besides the breeding of improved strains, which has resulted in the release of 45 high yielding strains, the work has spread to cover genetics, agronomy, plant physiology, biochemistry and field and storage pests of rice. Rice improvement work was started in 1919 and is now carried on at 15 research stations, located at Karjat, Ratnagiri, Phondoghat, Kumta, Sirsi, Panvel, Nawagam, Kosabad, Dabhoi, Vadgaon, Igatpuri, Radanagari, Mugad, Waghai and Kumta (salt land)

The research station at Karjat, started in 1919, is the chief centre of rice research in the state. This station serves North Konkan, an area of heavy black soil with 75–150 inches of rainfall and growing extensively a fine grained variety of rice. called *Kolamba*.

Madhya Pradesh: Madhya Pradesh state, situated in the centre of the country, has 8.8 million acres under rice cultivation and an annual production of 2.1 million tons. The state has only one rice research station which is located at Raipur. This station was started in 1908 and is engaged in breeding and agronomic investigations. So far 18 strains have been released.

Bihar: Bihar state, situated in the Gangetic plains of eastern India, has 13.3 million acres under rice cultivation, the largest rice acreage in any state of the country, with an annual production of 3.3 million tons.

Work on rice improvement started in Bihar as far back as 1914-15, the early work being mostly devoted to varietal trials and agronomic investigations. From 1932 the Indian Council of Agricultural Research has

helped to finance the breeding work and the result has been very successful. The main rice research station of the state used to be at Sabour. But recently the state is divided into 4 agricultural regions, each with a regional research station. Besides Sabour, which is now made a regional research station, the other three regional research stations are in Patna, Ranchi and Pusa and 10 sub-stations are proposed to be established. A total of 13 improved rice strains has been evolved.

Punjab: The Punjab, situated in North India, is relatively of minor importance among the rice growing states of the country. There are two rice research stations in the state: one at Nagrota Bagwan and the other at Gurdaspur.

The Nagrota Bagwan station was started in 1936 and seven improved strains have been released so far. Since wild rice is a serious problem in Kangra hills, work is in progress to breed purple pigmented varieties, which are easily distinguishable from the wild rice. It may be mentioned that the performance of three Chinese varieties and three *japonicas* has been found very promising in the hills.

The station at Gurdaspur was started in 1950. Prior to this, rice improvement work for the Punjab plains was carried out at Kala Shahi Kaku which is now in West Pakistan.

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RICE DISEASES IN INDIA

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Introduction

The rice crop in India suffers from practically all known diseases of rice, including those of parasitic origin. The following is a brief review of some of the important investigations that are currently in progress in the country.

Blast Disease of Rice

(Piricularia oryzae Cav.)

Nature and Extent of Losses

'Blast' infection usually causes a serious loss in seed-beds under favourable conditions. In severe cases, the entire foliage of adult plants may be destroyed, arresting their growth. Heavy losses occur when the 'neck' infection appears during the period of ear emergence.

No objective estimate of the loss due to the disease is now available. Investigations have been carried out at the Central Rice Research Institute, indicating that the loss in yield is in direct proportion to the severity of the infection. It was reported that under experimental conditions a loss of 45 per cent in Cuttack and of 60 per cent in Madras had been recorded due to the disease with certain varieties in certain seasons. However, for the sake of accuracy, a much larger scale of field survey is required.

Sources of Infection and Development of the Disease

The disease is claimed to be seed borne elsewhere, but in India no definite evidence has been found to show that it is so. It is considered that a secondary infection is a main cause of the disease. Probably the two kinds of grasses, *Panicum repens* and *Digitaria marginata*, which have been proved to be collateral hosts of the pathogen in Madras, serve as the sources of infection.

Of the several environmental factors that influence the development of the disease, the level of nitrogenous fertilization under which the crop is grown appears to be most important. Investigations conducted at Coimbatore, Madras, and at the Central Rice Research Institute, Cuttack, have shown that excessive applications of nitrogenous fertilizers pre-dispose the crop to infection. The rate of increase in susceptibility with increasing levels of nitrogen varies with different varieties of rice. A relatively resistant variety can tolerate 60-100 lbs. N per acre.

As to the other factors, experimental evidences available from Coimbatore and the Central Rice Reseach Institute show that neither potash nor phosphorus when applied alone or in combination with N has any effect on the disease.

The susceptibility of the rice plant to blast changes with its age: most susceptible

to leaf–blast infection in the tillering stage after transplanting, and less susceptible to foliar infection as it approaches the heading stage when 'neck' infection is apt to occur.

The climatic factors which favour blast development appear to be the range of temperature (24°–27°C), the high degree of relative humidity and dew formation. There are two seasons in a year in Cuttack in which blast attains its maximum intensity: September-October in the main crop season and February in the second crop season. The varieties which flower during September–October get 'neck' infection, while the late varieties still in the tillering stage during this period, get only leaf–infection, and escape 'neck' infection. Similarly, in February the crop gets leaf or neck infection according to its maturity. Down south in Madras, blast is severe only during December–January when most varieties come to ear and thus become exposed to infection in the neck.

Control Measures

Among the measures of blast control, may be mentioned the isolation of resistant varieties already in existence, the breeding of new resistant varieties through hybridization and spraying.

I. Breeding for blast resistance

a. At the Central Rice Research Institute. Nearly 500 rice varieties were tested for blast resistance, under both artificial infection in pots and natural field conditions. As a result, the following 14 varieties, BJ. 1, Sm. 8, Sm. 6, S. 67, Mtu. 5, C.P. 6, S. 624, AKP. 8, AKP. 9, Ch 55., H. 755, Sm. 9, C.P. 9 and PTB. 10, were selected as resistant or moderately resistant to blast. During 1954–55, five of the above variesties which are of early maturity were tried out in 22 different agricultural research stations distributed all over India and in all these stations, they proved to be resistant. During 1955–56, these varieties were again tried in 46 centres and their resistant characteristics were further confirmed. They are being subjected to a third test during the current year. After going through these three trials successfully, the resistance of a variety can be established. The resistant varieties with good yield under local conditions may be recommended for general cultivation right away, while the rest will be used for breeding purposes.

Another 490 varieties from the genetic stock collections has now been under observations for isolating resistant varieties. All these varieties are of early maturity, ripening in 110–120 days. They are being tested under both artificial infection in the seedling stage and field conditions.

Crosses have been effected between Co. 25, a hybrid released from Madras, resistant to blast and maturing in 170 days under Cuttack conditions, and Co. 13, a high yielding, short duration variety but highly susceptible to blast. F_4 and F_5 generations of the crosses are presently under observation and it is hoped that some early maturing, high yielding selections, resistant to blast, can be isolated.

b. In Madras State. Breeding for resistance to blast was started in Coimbatore as early as in 1926. Eighteen resistant varieties have been isolated. Co. 4, the most resistant rice variety so far found in India, is a selection from the local variety, *Gobi Anaikomban*. This is a late variety maturing in about 200 days under Madras conditions. Another selection, TKM. 1, is an early variety.

In Madras State, Co. 4, has always been used as a resistant parent. A number of crosses have been made with other varieties at Coimbatore, Aduthurai and Buchireddipalem (now in Andhra State). Fourteen resistant varieties have been evolved from these crosses. Recently, GEB. 24, and Co. 4 have been crossed and a number of hybrids of this cross show great promise.

Out of the above 14 hybrids, Co. 25, Co. 26 and Adt. 25 have been released as blast resistant for general cultivation. Another hybrid No. 6538 has been found to be resistant and will soon be released and the rest will be kept for further observations.

It has been shown that there is a close relationship between the extent of silicification of epidermal cells of rice plants and the degree of their resistance to blast attack. The rate of absorption of silica is higher with the resistant varieties at two vulnerable stages of plant growth to blast attack, namely: tillering and the ear emergence stage. Work in Madras has also shown that the number of stomatal openings in a unit area of a leaf is greater in a susceptible variety compared to a resistant one.

c. In Bombay State. Since 1950 all the improved varieties of Bambay State have been tested for blast resistance in the seedling stage under artificial infection conditions at Mahabaleswar, and as a result 12 varieties have been selected as resistant or moderately resistant. Several hybridization projects are presently in progress.

2. Control of blast by spraying

Since it is not immediately feasible to replace all the existing susceptible varieties with resistant ones, attention has been directed toward the control of the disease by spraying the crop with copper fungicides. To be effective, 4-5 sprayings are required in a season at the rate of 75-100 gallons per acre of the strength of 0.25 per cent metallic copper. This would cost about Rs. 50/- per acre. A study in progress at the Central Rice Research Institute indicates that a low-volume spraying at 20 gallons per acre is just as effective as a normal spraying at 100 gallons per acre. So the cost of spraying in a single season can be reduced to Rs. 10/- per acre.

There is another study made to see how effective organomercuric fungicides can be in controlling the disease. According to reports received from Japan they are more effective than copper compounds.

Helminthosporium Disease of Rice

(*Cochliobolus miyabeanus* [Ito et Kurib] Drechs ex Dastur= *Helminthosporium oryzae* Breda de Haan)

Nature and Extent of Losses

Like rice blast, helminthosporium disease also causes leaf-spots and 'neck' infection under favourable conditions. This disease [sometimes can be very severe. Epidemics due to the disease broke out in the Godavari delta and in Bengal in 1918 and 1942 respectively. The epidenic in Bengal caused a severe famine in that year. The record of the government farms at Chinsurah and Bankura showed that most of the recommended strains of rice suffered yield losses up to 90 per cent due to this disease. During these two epidemic years, some abnormal weather conditions were observed, like heavy rains or continuous cloudiness during the period of October-December when the weather is normally dry and cloudless. In the absence of such abnormal weather conditions helminthosporium disease seldom causes much damage to rice crop in India.

Sources of Infection and Development of the Disease

Under normal conditions, the pathogen of the disease stays in the rice seed between harvest in November-February and the main sowing season in June-July. However, the seed-borne pathogen can infect rice seedlings only at a temperature of 25°C or below. But the soil temperature in the main sowing season is often above 30°C. Therefore, the seed-borne infection is not important in the main season, though it may cause damage to the second sowing during November-December with lower temperatures. The source of seedling infection noticed immediately after germination in June-July has been attributed to air-borne conidia of *H. oryzae* which have been trapped over rice fields, in April-June even in the absence of a rice crop. Chattopadhyaya in Bengal has shown that *Leersia hexandra*, a weed in rice fields, is a collateral host of the pathogen, and it is probable that this grass is a source of infection for seedlings in June-July.

Studies with aeroscopes have shown that there is an increase in spore production whenever there is an increase in relative humidity and cloudiness. This effect is most evident during October, November and December. During the monsoon season when there is a frequent down-pour, the spore production and dispersal appear to be at a minimum.

Control Measures

Investigations on the control of the disease have been directed toward breeding resistant varieties and seed treatment with fungicides and hot water.

1. **Breeding for disease resistance.** Out of nearly 500 varieties examined six varieties, viz., Ch.13, Ch.45, T.141, T.498-2A, Bam. 10 and Co.20 have been isolated as relatively resistant to the disease under

both artificial infection in the seedling stage and natural infection in the seedling and adult stages. Five of these varieties are currently being tested at 46 centres in different parts of India and results obtained so far indicate that, except T.498-2A, others are relatively resistant to the disease in all centres. The resistant varieties will be used either for general cultivation or for breeding purposes. Another 490 early maturing varieties from the genetic stock collections have also been tested for their resistance to the disease.

2. Seed treatment. Since seedling blight occurs only in the colder months - December and January, it can be expected that seed treatment will be beneficial for the second crop sowing. . This is true with the seed treatment experiments carried out at the Central Rice Research Institute with different fungicides. Though increased germination and stand may be obtained with the seeds treated with fungicides, the effect on yield is not so evident.

Hot water treatment is also recommended for the control of seed-borne infection.

Stem-rot Disease

(*Leptosphaeria salvinii* Catt = *Helminthosporium sigmoideum* Cav. = *Sclerotium oryzae* Catt.)

Nature and Extent of Losses

This is one of the earliest diseases of rice noticed in India and occurs all over the country. During recent years it has caused serious losses in crop yields in Madras, Kashmir, Coorg and in the Punjab. The disease attacks the plants at all stages from seedlings to maturity. If the disease appears late in the season when the crop is nearing maturity, young tillers continue to arise and many green ears are formed which do not fill giving a characteristic appearance to the diseased crop.

Origin and Spread of the Disease

The disease spreads by the minute and black sclerotia of the fungus. The sclerotia survive in rice stubbles and soil and infect the next rice crop. They also float down on irrigation water and lodge on rice stems and start infection.

Excessive applications of nitrogenous fertilizers favour the development of the disease while applications of potassium and phosphorus in sufficient amounts have the opposite effect. The organism thrives best in acid conditions and so fields with inadequate drainage facilities predispose the crop to stem-rot infection.

Control Measures

Since the fungus remains in the infected stubbles and in the soil, it is recommended that the stubbles should be burnt and the water-logged conditions in the fields improved.

Hector in Bengal has observed that Dudsar, one of the departmental varieties, was resistant to the disease under severe

conditions of natural infection. Similarly, in the Punjab, Parasar and Luthra have observed that Basmati 370, Basmati 3, Mushkan 7, Mushkan 4 and Bara 62 are highly resistant to the disease. Currently a scheme is in progress in Madras State to study the conditions of outbreak of stem-rot in order to devise suitable control measures.

Foot - Rot

(*Gibberella fujikuroi* (Saw) Wr. = *Fusarium moniliforme sheld*)

Foot-rot of rice occurs in many parts of India, especially in delta areas in Madras State. It causes pale and elongated growth of seedlings which subsequently die off. The infection is seed-borne but it is easily controlled by seed treatment with organo-mercuric fungicides. As a matter of fact in Madras and Andhra states where the disease is usually severe, the plant protection department has successfully controlled the disease by means of seed treatment.

Root - rot Complex

This is a physiological disease first reported by Dastur in 1937 and subsequently the disease has been observed everywhere in India, when rice is grown under water-logged conditions. Under such conditions the plant roots become highly attenuated and the leaves yellow or brown. Recent investigations in Bengal have shown that plants growing in soil continuously fertilized with phosphorus remained comparatively free from root-rot symptoms.

At the Central Rice Research Institute it was observed that the following varieties are relatively resistant to the disease: PTB. 10, N. 136, Benibhog, ADT.4 and ADT. 15. The disease can be effectively controlled by proper drainage and applications of nitrogenous fertilizers.

Uffra

This disease, caused by a nematode, is serious in Bengal. The worm survives in the seed and in the affected stubbles. Water stagnation favours its development. It is therefore recommended that all stubbles of the crop should be burnt. Light seeds which generally habour a high percentage of the worms are to be floated out in salt water treatment and only the plumpy and healthy ones are to be used for sowing. Hot water treatment is also helpful. Water in the fields should be kept gently flowing.

Future Program of Work

With the expansion of rice production in the country, the problem of rice disease control is getting more acute as time goes on. Objective methods of assessing the losses caused by the diseases have to be devised.

The breeding program for evolving more suitable varieties resistant to the diseases has to be further intensified in all rice growing states in the country. Those resistant strains selected at the Central Rice Research Institute from the genetic stock

collections will be tested in all rice stations in the country and all promising varieties will be used as parents in hybridization programs.

Further studies will be made on the conditions under which the diseases may develop into epidemics so that a forecast system can be worked out.

Such control measures as spraying and dusting to control rice diseases have never been popular among the rice growers due to the non-availability of spraying equipment and the high cost involved in spraying. These have to be investigated and improved.

Lastly, a careful watch should be maintained over what are at present minor diseases lest they might one day become important and destructive.

FERTILIZER USE IN RICE PRODUCTION IN INDIA

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Rice crop occupies about 73 million acres in India, which is about 30 percent of the total area under cultivation, and is grown in all types of soils, provided enough water is available. The rice crop depends largely upon the south-west monsoon. The low-lying areas usually remain water logged during the crop season. Due to the continuous cultivation of rice on the same land year after year and the absence of any manuring, the soil has been depleted of its fertility and the average acre yield of rice in the country is as low as 800 lbs. of milled rice per acre.

The acute food shortage in the post-independence period as well as the pressure of growing population has increased the demand for more food production. Since the scope for further expansion in land area under rice is limited, to increase acre yield by adopting intensive methods of cultivation and by the extensive use of manures and fertilizers has become increasingly important in recent years. Use of manures and fertilizers to the best advantage, however, requires knowledge of their effects on yield response to be obtained under different soil and water conditions. Manurial experiments on rice crop have been conducted by various state agricultural stations and the results have been reviewed from time to time. But most of the experiments were conducted on government farms, where the fertility level is usually high and improved methods of cultivation are practised. So in recent years, greater emphasis has been given to yield tests conducted in cultivators' fields, and interesting results have been obtained. A nationwide scheme of such soil tests is now under consideration, to be carried out under different soil, climatic and water conditions. The data when available would be very valuable for formulating a national fertilizer policy.

General Indications of Fertilizer Experiments

From the limited number of manurial experiments conducted on rice in the country, it has become apparent that the application of both organic manures and inorganic fertilizers, particularly nitrogenous ones, gives appreciable increase in yield. The rate of response, of course, varies with the initial fertility of the soil, the season and method and time of application. Generally speaking, rice soils in India are mostly deficient in organic matter and nitrogen, moderately deficient in phosphates, but well supplied with potash. Recent experiments on cultivators' fields in some of the states however indicate that phosphates when applied with nitrogen gives additional response; and that potash is beneficial, only in certain areas.

Organic Manure

In tropical regions, the organic matter in the soil decomposes rapidly and there

is therefore a great need for replenishing it. This is usually done by applying cattle manure in the form of compost, but the quantity available in the country is not enough.

Green manuring has proved to be most beneficial under wet conditions as prevailing in most of the rice growing areas in the country. Green matter incorporated in the soil decomposes easily and gives effect on crop yield, which is as good or even better than the use of artificial fertilizers. An average crop of 'dhaincha' *(Sesbania aculeata)* or 'sunnhemp' *(Crotalaria juncea)* may yield 5,000–8,000 lbs. of green matter per acre. Experimental data indicate that when this quantity of green matter is incorporated in the soil, it is not necessary to supplement it with any inorganic nitrogenous fertilizer. The average response obtained with 'dhaincha' green manuring as compared to the use of ammonium sulphate in one of the experiments at Cuttack is given in Table 1.

Table 1

Response of Paddy in pounds per acre to Different Treatments[1]

(Average of 5 years at the Central Rice Research Institute, Cuttack)

Levels of nitrogen (lbs. N/A)	Fields treated with ammonuim sulphate	Fields treated with 'dhaincha' green manuring
20	+ 420	+ 652
30	+ 662	+ 709

Incorporation of the same amount of green leaf matter in the soil is found to be as efficient as growing the crop in *situ*.

For the conditions existing in low land rice areas in India, *Sesbania aculeata* and *Sesbania speciosa* are the most suitable crops to be used for green manuring purposes. Among other crops tested, *Phaseolus semierectus, Casssia leschenaultiana, Aeschynomene americana* and some *Crotalaria sp.* have been found to be promising. *Glyricidia maculeata,* a quick growing shrub which can be easily grown on field or channel bunds, produces a heavy crop of succulent leaves which can be cut and applied to the soil as green manure.

Concentrated organic manures like oil-cakes, containing a fairly high percentage of nitrogen, have been tried and found just as effective as ammonium sulphate or green manuring in increasing acre yield. But due to their high cost and their utility as valuable animal feeds, to use them as manure for rice crop is not economical.

1 No manure control plot yield = 2,170 lbs. per acre.

Nitrogen

An outstanding result obtained from the various manurial experiments conducted on a wide variety of soil conditions is the universal response to nitrogenous fertilizers applied in one form or another. Extensive investigations have been conducted to determine the optimum dose of nitrogen, the comparative efficiency of various nitrogenous fertilizers and the best method and time of application.

Optimum Doses The efficient use of nitrogenous fertilizers varies with the initial fertility status of the soil, the optimum rate ranging from 20 to 60 lbs. of nitrogen per acre. On the average, there is an increasing response up to 40 lbs. of nitrogen per acre, beyond which the response generally declines. With a dose of 20–30 lbs. of nitrogen per acre, an increase of about 300–500 lbs. of paddy per acre, or about 15–16 lbs. of paddy for every lb. of nitrogen applied can be expected. The average response over a period of seven years obtained in an experiment with varying doses of sulphate of ammonia applied in conjunction with compost is given in Table 2.

Table 2

Response of Paddy in pounds per acre to Different Treatments

(Average of seven years from 1949–50 to 1955–56, Central Rice Research Institute, Cuttack)

Level of nitrogen (lbs. N/A)	Fields without basal dressing	Fields with basal dressing of compost at 8,000 lbs./A
N_0	–	366
N_{20}	307	654
N_{40}	592	620
N_{60}	615	404
N_{80}	421	–24

Comparative Efficiency of Various Fertilizers Out of the different forms of nitrogenous fertilizers used, ammonium sulphate has been found the most suitable for rice. An experiment has been in progress at the Central Rice Research Institute for the last three years and the various nitrogenous fertilizers have been applied on the basis of equal amounts of nitrogen, namely, 20 and 40 lbs. N per acre. The results obtained are given in Table 3.

Table 3

Efficiency of Various Nitrogenous Fertilizers
(Average of 3 years 1953–56 – Central Rice Research Institute, Cuttack)

	Yield of paddy in lbs. per acre			Comparative efficiency, with ammonium sulphate as 100
	20N lbs.	40N lbs.	Average	
1. Ammonium sulphate	2,506	2,761	2,634	100
2. Ammonium phosphate	2,453	2,648	2,551	97
3. Ammonium chloride	2,402	2,670	2,536	96
4. Ammonium sulphate–nitrate	2,445	2,355	2,520	96
5. Ammonium nitrate	2,297	2,355	2,325	88
6. Urea	2,083	2,447	2,265	86
7. Calcium cynamide	1,986	2,228	2,107	80
8. Sodium nitrate	2,021	2,134	2,077	79
No manure (control)			2,037	

All the fertilizers, except sodium nitrate and calcium cynamide, have given appreciable increases in yield, with ammonium sulphate giving the highest. The yield responses obtained with ammonium phosphate, ammonium chloride and ammonium sulphate-nitrate were not significantly different from those with ammonium sulphate, as indicated in the above table. Therefore these could be used as alternative fertilizers for rice and their use will, however, depend upon their comparative costs and availability

Deep Placement of Ammonium Sulphate. The customary practice of applying ammonium sulphate to rice crop throughout the country is top dressing soon after the crop is established. By such method of application in water logged soils, a considerable amount of the nitrogen applied is lost through denitrification taking place in the soil. Results of experiments conducted at the Central Rice Research Institute indicate that the sub-surface application of ammonium sulphate, either as basal dressing in dry soil conditions or as top dressing in the form of pellets, is more beneficial than the customary surface application. The yield response obtained with different methods of application in an experiment conducted for four years is given in Table 4.

Table 4

Different Methods of Applying Ammonium Sulphate
(Central Rice Research Institute, Cuttack)

Season	No. manure control plot yield in lbs./acre	Response of paddy in lbs. per acre, ammonium sulphate at 20 lbs. N/A	
		Surface application	Sub-surface application
1949–50	1,538	169	259
1950–51	1,817	253	315
1951–52	2,160	98	230
1952–53	1,469	251	372
Average	1,746	193	294
Response of nitrogen per lb.	–	9.7	14.7

Thus it can be seen that the sub-surface application gives a higher yield response than the customary surface application.

Optimum Time of Application Experiments are currently in progress to determine the optimum time of application of ammonium sulphate to rice crop, and to see whether the entire quantity should be applied in one dose or in split doses at different stages of plant growth. It has been found that application in three split doses, i.e., at planting, one month after planting and 2-3 weeks before flowering, was more efficient than the entire quantity applied in one dose.

Production and Consumption Trends of Nitrogenous Fertilizers Before independence, only a limited amount of sulphate of ammonia was imported. In recent years, since great importance has been laid on the increase of crop production, local fertilizer industry has been rapidly developed. The present production capacity of the country is about 0.4 million tons and it will be further expanded during the second five year plan period. Though there are no separate figures for sulphate of ammonia used on rice crop, the following table will show the trend of fertilizer production and consumption in the country.

Table 5

The Annual Production and Consumption of Ammonium Sulphate in India

Year	*Production in tons*	*Consumption in tons*
1937-38	–	53,276
1945-46	27,459	69,260
1950-51	47,308	272,176
1954-55	340,222	426,536

It is estimated that by 1960 the annual consumption of nitrogenous fertilizers in terms of ammonium sulphate will be about 1.8 million tons.

Phosphorus

In general the response to phosphatic fertilization of rice crop is not as large as in the case of nitrogen, but experimental results have shown that there are general phosphate deficiencies in cultivators' fields and yields can be pushed up in many places by applying phosphatic fertilizer in combination with nitrogen. Before 1952, many fertilizer trials, conducted at experimental stations all over the country, had shown that unlike nitrogen, phosphate generally gave no response, except in certain places in the states of Madhya Pradesh, Bihar and Bombay and it was often concluded that phosphate was not needed in alluvial paddy soils.

Since 1949-50 Mukerjee has conducted a large number of field trials on cultivators' fields in the state of Bihar and found a positive response to the use of superphosphate as shown in Table 6 and concluded that the absence of reponse in the past on experiment stations may be due to higher fertility status of the soil, as a result of continuous use of organic manures and better system of cultivation and management obtained there.

Table 6

Response to Phosphate in Bihar on Rice

(Increase in yield over no-manure in lbs./acre)

Year of trial	*No. of experiments conducted*	*P_2O_5 per acre*	
		20 lbs.	*40 lbs.*
1949-50	576	–	262
1950-51	1,334	–	246
1951-52	1,245	–	279
1952-53	625	–	246
1953-54	759	237	366
1954-55	710	270	344

Following the experiments in Bihar, trials on cultivators' fields were started all over India. Results from 9 major rice growing states showed that on the average nitrogen alone gave a response of 145 lbs. of paddy per acre; and nitrogen and phosphate in combination gave a yield increase of 255 lbs. of paddy per acre. Further extensive trials conducted in 1953-54 on cultivators' fiields also amply showed response to

phosphatic fertilization on various soil types in the country, averaging 217 lbs. of paddy for 20 lbs. P_2O_5 level. These trials also showed that fertilizers, such as super-phosphate or ammophos, when placed 2 1/2 inches below the seed gave better results than when broadcasted.

Good response to the combined use of nitrogen and phosphate is also reported by Desai and Krishnamurthy on black soils in Hyderabad State. These soils ordinarily could not grow a good crop of rice, but when fertilized with nitrogen and super-phosphate gave considerable increase in yield as shown in Table 7.

Table 7

Effect of Super-phosphate Application on Black Soils at Himayetsagar Farm, Hyderabad

Treatment	Grain yield in lbs. per acre
1. No manure	655
2. Ammonium sulphate, 45 lbs. N/acre	1,185
3. Super-phoshate, 45 lbs. P_2O_5/acre	1,149
4. Combination of nitrogen and phosphate as at 2 and 3	3,552

By continuous application of nitrogenous and phosphatic fertilizers on these soils yields have been pushed up considerably from 440 lbs. per acre in 1949 to 6,129 lbs. per acre in 1953.

For general application, it is recommended that 30 lbs. of P_2O_5 plus 30 lbs. of N per acre can be profitably used. All the phosphatic fertilizers are used as basal dressing at planting. In the country-wide drive' for increasing rice production by adopting Japanese method of cultivation, a level of 20-30 lbs. P_2O_5 per acre along with basic nitrogenous fertilizers is generally recommended. Phosphatic fertilizers are also recommended to be used on green manuring crop to increase its yield, thus increasing nitrogen supply when thc crop is ploughed under before planting rice.

Most commonly used is super-phosphate, but bone-meal, rock phosphates, ammophos and niciphos are also used. Due to the drive for intensive cultivation, use of phosphatic fertilizers is of late getting popular and consumption of super-phosphate is on the increase. The production of super-phosphate in the country has been increased from 61,018 tons in 1951 to 105,056 tons in 1954. Its production will be further expanded in order to cope with

the demand for increased food production in the 2nd five year plan.

Potassium

Potassium fertilizers have generally given no response except in the state of Bihar. In Bihar an increase in yield of about 205 lbs. per acre can be obtained with 20 to 40 lbs. of K_2O applied. However, further trials on cultivators' fields on a much larger scale will have to be carried out.

Lime

To use lime to correct soil acidity has been tried out in the country but in general the response has been small and did not pay for the cost involved. At the Central Rice Research Institute there has been a long range experiment to study the the effects of continuous use of ammonium sulphate on the same land for the past eight years, along with small quantities of lime showing no appreciable effects on crop yield. But when the amount of lime used was increased to 2,000 lbs. per acre at the time of pudding an increase of 395 lbs. of paddy per acre was obtained due to its mineralizing effect, thus making nitrogen in the soil readily available to the crop.

INSECT PESTS OF RICE IN INDIA AND THEIR CONTROL

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Insects damage rice crop in the field as well as in storage, causing a considerable amount of loss in the country.

Conditions suitable for rice cultivation are also favourable for the rapid multiplication of insects. Hence, most of the major insects causing damage to rice are found in all the rice-growing areas. Furthermore, varieties of rice that mature at different times in India are often grown side by side, year after year, over vast areas, affording excellent conditions for the uninterrupted breeding and dispersal of the insects.

The prevalence of insects and their damage to crops are influenced by environmental factors. An insect which is normally of minor importance may suddenly assume epidemic proportions under favourable conditions in a certain year.

The following is a brief review of the progress of research made on some of the most important insect pests of rice in India.

Insect Pests in the Field

Stem borers:

1. *Schoenobius incertellus*, Wlk. – yellow stem borer
2. *Chilo simplex*, Butl. } – striped rice borer
3. *Chilo zonellus*, Swin. }
4. *Sesamia inferens*, Wlk. – pink borer
5. *Scirpophaga innotata*, Wlk. – white rice moth borer.

All these five species of stem borers are found in all rice growing areas of the country but their relative importance varies with different regions. It is reported that their usual damage runs from 3 to 65 per cent of the crop, but as much as 95 per cent of the crop has been reported damaged in a year in the Punjab. The second or summer crop usually suffers most from the pest, with the result that farmers are often reluctant to grow a summer crop of rice.

Of the five species, the yellow stem borer is the most injurious, particularly in areas of double cropping, causing damage to the rice crop both at the seedling and flowering stages. The characteristic symptom of the damage by this pest at the seedling stage is the presence of a 'dead heart' which easily comes off when pulled. At the flowering stage, the attack is indicated by the appearance of white earheads, with chaffy grains.

The striped rice borer is a serious pest in Bihar and Orissa. The damage caused by it is similar to that caused by the yellow stem borer but the following characteristics

are distinguishable: (1) the rice stalk becomes bleached and breaks down; (2) the leaf sheath is nibbled and becomes discoloured; and (3) many larvae congregate on earheads and cause chaffy grains

The pink borer is a serious pest in Andhra, Hyderabad and Madras states. The symptoms and damage are similar to those caused by the yellow stem borer, but the larvae tunnel inside between the leaf sheath and the stalk.

The symptoms and damage by the white rice moth borer are essentially similar to those caused by the yellow stem borer. This borer is particularly serious in Madras, Orissa and the Punjab.

The chief problem in the control of stem borers is that egg masses of the yellow stem borer or the white rice moth borer are covered with dense buff–coloured hairs making penetration of insecticides difficult. Moreover, the larvae which cause destruction to the rice crop bore into sheaths and stems and remain there concealed while feeding. When they once enter into the stems, it is difficult to control them with any insecticide. On account of these difficulties, the insecticidal treatments have to be directed against the ovipositing adults and newly hatched larvae. It is therefore essential to determine the time of brood emergence or the prevalence of moths to arrive at the correct timing of insecticidal applications. The number of broods or generations in a year is variable, from three to five depending upon the meteorological factors and cultural practices. At Cuttack, two main broods, viz., one during November-December and the other during February–April, are distinguished with considerable overlapping of generations. The first brood attacks the late planted monsoon crop and the seedlings of a summer crop, causing white earheads in the former and dead hearts in the latter. The second brood attacks the summer crop, causing either white earheads or earheads with partially filled and unfilled grains.

The methods of control suggested by earlier workers, viz., clipping leaf blades to remove deposited eggs, setting up light-traps to catch adults and ploughing rice stubbles to destroy pupae, though contributing to minimise the damage to some extent, are far from satisfactory.

Recent trials with chlorinated hydrocarbon compounds and organophosphorous compounds in the different states indicated a considerable success in the control of stem-borers. Investigations at the Central Rice Research Institute on the different methods of application of chemicals to control stem borers, have revealed that a light dusting with 5 per cent BHC twice in the nursery is sufficient to ensure insect free seedlings.

Sprayings on the transplanted crop shold be directed against the ovipositing moths and the newly hatched larvae. The first spray is to kill the adults, while the second spray, to be applied 8 to 10 days later, is to check the newly hatched larvae. Folidol-0.08 per cent or endrin-0.04 per cent, was found most effective for these purposes. This schedule of spraying opera-

tions at the Central Rice Research Institute reduced the incidence by 84.0 per cent and increased the yield by 54.0 per cent. BHC or DDT sprays at 0.20 per cent concentration were also effective but since the residual toxicity was far less, the number of sprayings should be increased.

However, the more rational and practical approach to the problem of control of pests like stem borers is by the biological method, which has not yet been fully exploited and there is a need for intensive research.

In a search for parasites for use in the biological control of stem borers, the following new species have been brought to light:

1. *Aprostocetus israeli* — on grubs of *Chilo* sp.
2. *Syntomosphyrum israeli* — on eggs of *Schoenobius incertellus* Wlk.

Studies on varietal susceptibility to stem borers indicate that, in general, the incidence is higher with scented varieties.

The estimation of loss caused by stem borers has been attempted by several workers. To make a correct appraisal of the damage caused by them it is necessary to make separate estimates of the losses occuring at the seedling and earhead stages. At the Central Rice Research Institute, it was found that for every unit per cent increase in white earheads, the decrease in yield is 0.60 per cent (Israel and Veda Moorthy, 1955).

Gallfly: *Pachydiplosis oryzae* — W-M-Mani — rice gallfly or rice gall midge

This insect occurs in Assam, Bihar, West Benga, Madhya Pradesh, Hyderabad, Orissa, Andhra, Madras and Mysore states, causing extensive damages to rice. Eggs are laid on sheaths and blades of leaves either singly or in clusters. On hatching, the grub penetrates into the primordial cone where it develops. As a result of the irritation caused by this grub, the central shoot turns into a slender tubular outgrowth called 'silver shoot'. The longitudinal margins of the leaf sheath are glued together to form a silver shoot at the top of which is a small leaf-blade.

Studies on the seasonal abundance of gallflies at Cuttack revealed that this pest was prevalent from July to December and the peak period of infestation fluctuated between the end of September and the end of November. The number of broods varies from six to eight with considerable overlapping of generations. Investigations on the incidence of gallflies in relation to the age of the crop revealed that infestation was always higher with the 90 day than with the 60 day old crop, irrespective of the time of transplanting. Studies on varietal reactions to gallflies indicated that green non-scented varieties had higher infestations than either green scented or purple pigmented varieties. Among the green non-scented varieties, infestation is always higher with varieties which have higher tillering capacity. Inves-

tigations at the Central Rice Research Institute on the incidence of gallflies in relation to tillering have revealed that the incidence, at the early stage of vegetative growth of the crop, would induce vigorous tillering which would come to flower if not reinfested.

Growing early varieties of rice to avoid the peak period of the pest has been recommended but such early varieties are invariably poor in yield. The entire larval and pupal stages are spent in a single stem and the newly hatched grub does not wander much or feed outside. The adults are short lived. On account of these habits of the insect together with the grub remaining well protected inside the stem, spraying with insecticides has not resulted in effective control. At the Central Rice Research Institute spraying with 0.08 per cent Folidol or 0.04 per cent endrin four times during the vegetative growth stage of the crop to synchronise with the brood emergence, reduced the incidence by 48.0 per cent resulting in an increase of 15.0 per cent in yield.

Investigations on the estimation of the loss due to gallflies at Cuttack showed that for every unit per cent increase in incidence there would be a loss of 0.5 per cent in yield (Israel and Veda Moorthy, 1955). The natural parasitisation of gallfly grubs was found to be 89.0 per cent between the end of October and the end of November. Two new parasites on grubs of gallflies were found at Cuttack :

(1) Proleptacis oryzae and

(2) Telenomus israeli.

Rice Bugs: *Leptocorisa acuta*, Thun. / *Leptocorisa varicornis*, Fabr. – rice earhead bugs, stink bugs or *gundhi* bugs

Both of these two species occur as serious pests in Assam, Bhopal, Bihar, Delhi, Madhya Pradesh, Madras, Orissa, Rajasthan, Travancore-Cochin, Uttar Pradesh, Madhya Bharat, Vindhya Pradesh and West Bengal.

In 1953 they assumed epidemic proportions and infested seven to eight million acres of rice in India. Both nymphs and adults attack rice at the earhead stage and suck juice from the developing grains. Grains at the milk stage are attacked, while mature grains are immune. A hole is left in the grain where the bug punctures, around which a brownish spot develops. The bugs emit an offensive smell and their presence can be recognised by the smell from a distance.

Hot and humid conditions seem to be favourable for their rapid multiplication. At the flowering time of rice fields, they migrate from grasses where they hibernate to rice plants and cause damage. Ununiform ripening of rice plants favours their multiplication and the successive generations migrate from early to late varieties, with the result that they may become a serious menace. The bugs fly from one field to another usually at night.

Dusting with 5 per cent BHC, DDT or aldrin in the early morning hours at the rate of 15 lbs. per acre effectively controls the pest (Israel and Rao, 1954).

Rice hispa and leptispa: *Hispa armigera,* Oliv. – rice hispa
Leptispa pygmaea, Baly. – rice leptispa

Rice hispa is a serious pest in the southern and eastern states of India, though it is distributed all over the country. The loss in yield caused by this pest is estimated to be about 20 per cent but it was reported to have caused from 30 to 65 per cent damage in Hyderabad. The grubs mine into leaf tissues and pupate inside causing withering of leaf tips. The adults feed on leaves causing white parallel lines. There are three to four generations a year.

Rice leptispa is a serious pest in Mysore and Assam and the damage due to this pest is similar to that caused by hispa. The grubs feed on the upper surface of the leaves which usually fold over so as to conceal the grubs.

Studies on the incidence of rice hispa in relation to season and age of the crop, revealed that the insect prefers young plants. In 1948 this pest appeared in an epidemic at the Central Rice Research Institute, when the temperature varied from 82.0°F to 92.2°F and the humidity from 75.0 to 98.0 per cent.

At the Central Rice Research Institute, trials to control the pest revealed that dusting with 5 per cent BHC, DDT or endrin, or spraying with 0.20 per cent BHC was effective in killing the adults. Spraying with 0.08 per cent Folidol or 0.04 per cent endrin was found effective in controlling both the adults and the mining grubs.

Grasshoppers: *Hieroglyphus banian,* F. I. – rice grass hopper
H. nigrorepletus, Bo. – Phadka grass hopper
Oxya velox, F. – paddy small grass hopper
Colemania sphenarioides, B. – Deccan wingless grass hopper

There are 13 species of grass hoppers, of which the above 4 are serious pests on rice. They are distributed throughout India, causing 1 to 20 per cent loss. Both nymphs and adults feed on leaves. In case of severe infestation the plants may be entirely eaten or reduced to mere midribs and stalks. Even tender grains are nibbled.

As the eggs are laid in the soil, deep ploughing of fields and scraping of field bunds to destroy egg pods, poison baits with sodium fluosilicate have been recommended. But dusting with 5 per cent aldrin, BHC or DDT on the crop and on field bunds controls this pest effectively.

Leaf hoppers: *Nephotettix bipunctatus,* Fab. }
Nephatettix apicalis, Mots. } – rice jassids
Nilaparvata sordescens, Linn. – fulgorid

Nine species of leaf hoppers are recorded in all the states of India and the above three are the most important and occasionally cause serious losses. They infest young crops especially in ill drained plots. Both nympths and adults suck juice from sheaths and blades of leaves, as a result of which the leaves turn yellowish brown and dry up. In case of severe infestation, earhead formation is retarded.

At the Central Rice Research Institute the following methods were found effective to control them (Israel and Rao, 1954):

1) dusting with 5 per cent BHC or aldrin, or spraying with 0.08 per cent Folidol or 0.04 per cent endrin;
2) better drainage; and
3) applying ammonium sulphate as a top dressing at the rate of 10 to 20 lbs. of nitrogen per acre to help the crop to recover from the damage by hoppers.

Army worms and cut worms: *Spodoptera mauritia,* Boisd. – rice swarming caterpillar
Cirphis unipuncta, Haw. – cut worm

These are sporadic pests distributed in all parts of India. The caterpillars cause damage at the seedling stage and they feed mainly at night. The number of generations varies from 2 to 4 in a year.

Spraying with 0.20 per cent BHC or DDT, or dusting with 5 per cent BHC or DDT controls this pest. However, spraying with 0.08 per cent Folidol or 0.04 per cent endrin is found to be more effective.

Rice case worm and leaf roller: *Nymphula depunctalis,* Gn. – rice case worm
Cnaphalocrocis medinalis, Gn. – rice leaf roller

The rice case worm occurs as a serious pest in lowlying rice lands. The larva cuts leaves and forms tubular cases that remain attached to the stem, a little above the surface of water in fields. Earhead formation is retarded when severely infested.

The rice leaf roller is a sporadic pest. The larva scrapes the leaf surface and remains inside the folded leaf.

At the Central Rice Research Institute, spraying with Folidol 0.08 per cent or endrin 0.04 per cent effectively controls these pests.

Rice mealy bugs and root aphids: *Ripersia oryzae,* Gr. – rice mealy bug
Tetraneura hirsuta, Butl. – root aphid

Mealy bugs are serious pests in upland areas and the infestation is localised. They are found in colonies between the leaf sheath and the stem. Root aphids, like the mealy bugs, are also found in colonies just below the soil surface. In both cases of infestation, leaves appear curled and dried.

Spraying with 0.08 per cent Folidol for the mealy bugs and spraying the soil surface around infested plants with 0.10 per cent Folidol for root aphids effectively control the pests (Israel and Rao, 1955).

Rice thrips: *Thrips oryzae*, Will.

These insects suck juice from leaf tissues, causing the leaf to roll inwards and wither. Severe infestation retards tillering.

Spraying with tobacco decoction, pyrocolloid (a pyrethrum product) at the rate of one ounce in two gallons of water, 0.05 per cent Folidol, or 0.02 per cent endrin gives effective control.

Pests of Stored Rice

Rice in storage is susceptible to damage by insects, rats and dampness. The loss of rice caused by insect pests in storage in India is reported to be about 5 per cent of its total production. Among a large number of storage insects, the following five are most serious:

Sitophilus oryzae, Linn. — rice weevil or black weevil
Sitophilus granarius, Linn. — granary weevil
Rhizopertha dominica, F. — lesser grain borer
Tribolium castaneum, H. — red rust flour beetle
Sitotroga cerealella, Oliv. — rice grain moth or angoumois grain moth

The adults and larvae of the beetles cause damage to the grain, while Sitotroga is destructive only at its larval stage. Owing to their minute size these pests often pass unnoticed till their population becomes enormous.

Experiments have revealed that the rice weevil and the rice moth start infesting the developing grain in the field and reach the storage house along with the infested grain and there under favourable conditions they multiply rapidly. It is therefore important that the freshly harvested grain should be dried to eliminate the initial population of insects and reduce the moisture content of the grain.

When rice is stored in bags, the infestation can be controlled by dusting with 4 per cent BHC or 5 per cent DDT at the rate of 1 lb. per 100 sq. ft. surface. If grain is stocked in bulk, fumigation with Killoptera or Chlorosol at the rate of 4 lbs. per 100 mds. of grain under an air-proof cloth before stocking is effective. Grain which is set part for seed purposes can be kept by mixing with either BHC or DDT at the rate of 2 ozs. per 125 lbs. of grain with no ill effects on its viability.

At the Central Rice Research Institute it was found that the powder of the dried rhizomes of *Acorus calamus* (Aroidae), popularly known as 'sweet flag', when mixed with the grain at the rate of 1 lb. in 100 lbs.

of grain was more effective than dusting with BHC or DDT (Israel and Veda Moorthy, 1953). The grain thus treated did not have any unpleasant odour when it was cooked. But at present *Acorus calamus* is cultivated only in limited areas and therefore it is not available for extensive use.

Though rice is usually stored as unhusked grain, large stocks are also stored after milling. Recently investigations at the Central Rice Research Institute have revealed that white rice is more susceptible to insect damage than parboiled rice and husked rice is more susceptible than polished rice.

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THE FIFTH SESSION OF THE INTERNATIONAL RICE COMMISSION

Calcutta, India, 12 to 19 November 1956

The Fifth Session of the International Rice Commission will be held at Calcutta, India, from 12 to 19 November 1956 through the kind invitation of the government of India. Just prior to this, the *ad hoc* Working Group on Storage and Processing of Rice will also meet at Calcutta from 5 to 10 November 1956. Letters of invitation to the member governments to be represented at these meetings have been sent out by the acting Director-General of FAO.

The Working Party of Fertilizers and the Working Party on Rice Breeding will not meet in 1956, but they are expected to hold their next meetings in 1957. This is necessary partly because these two Working Parties, which are well established, are currently working on long range programs, which require a much longer time to produce any substantial results; and partly because the three newly organized *ad hoc* Working Groups have to be served. So it is found both necessary and desirable to have the two Working Parties meet once in two years from now on, instead of annually as in the past.

The provisional agenda for the Fifth Session of the International Rice Commission and those for the meeting of the *ad hoc* Working Group on Storage and Processing of Rice are given below.

International Rice Commission

Fifth Session

Culcutta, India, 12 to 19 November 1956

Provisional Agenda

1. Opening of Session
2. Election of Officers
3. Adoption of Agenda
4. Progress Report by Executive Secretary on the Work of the Commission since its Fourth Session, including a financial statement regarding cooperative projects to which Member Nations have made special contributions.
5. Designation of Committees and Assignments of any Topics to be discussed initially in committee.
6. **Improvement of Rice through Breeding**
   Consideration of the report of the Sixth Meeting of the Working Party on Rice Breeding, and subsequent developments.

7. **Improving Rice Production through Better Fertilizing Practices**
Consideration of the report of the Fifth Meeting of the Working Party on Fertilizers, and subsequent developments.

8. **Problems of Soil, Water and Plant Relationships in the Production of Rice**
Consideration of the report of the *ad hoc* Working Group on Problems of Soil, Water and Plant Relationships in Rice Production.

9. **Problems of Mechanization of Rice Production**
Consideration of the report of the *ad hoc* Woking Group on Mechanization on Rice Production.

10. **Reducing Losses in Rice through Improved Operational Methods**
Consideration of the report of the *ad hoc* Working Group on the Storage and Processing of Rice.

11. **Consideration of action which might be taken to reduce losses of rice in the field**

12. **Recent developments on nutritional problems related to rice**

13. **Recent developments on the use of rice fields for fish culture**

14. Budgetary Proposals covering any Projects requiring Special Contributions

15. Other Business

16. **Time and Place of Sixth Session, and of forthcoming Meetings of Working Parties**

17. Adoption of Report.

Meeting of the *ad hoc* Working Group on Storage and Processing of Rice

Calcutta, India, 5 to 10 November 1956

Provisional Agenda

1. Opening of the Meeting
2. Election of Chairman and Vice-Chairman
3. Adoption of Agenda
4. Review of field practices affecting storage and processing
5. Losses in stored rice
6. Review of existing storage facilities and requirements for short, medium and long term storage of rice
7. The importance of preventive measures in the protection of stored rice from insect pests, rodents and fungi
8. Recent developments in the control of insect pests infesting stored rice

9. Testing equipment for determining the quality and potential milling results of paddy
10. Machinery and methods for cleaning and grading of paddy prior to milling
11. Machinery and methods for husking of paddy
12. Machinery and methods for whitening and finishing of rice
13. Machinery and methods for grading milled rice and by-products
14. Lay-outs of complete processing plants
15. Equipment and practices for parboiling of paddy
16. Training personnel in storage and milling and the need for training centers
17. Other business
18. Adoption of the Report and proposals for consideration of the International Rice Commission
19. Closing of the Meeting.

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